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INDOOR AIR QUALITY TEST PROTOCOL FOR HIGHRISE RESIDENTIAL BUILDINGS

Final Report

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part IX of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC, therefore, has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds.

DISCLAIMER

This study was conducted by Buchan, Lawton, Parent Ltd for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publications.

EXECUTIVE SUMMARY

This manual provides a protocol for the assessment of air quality in highrise residential buildings. The protocol is based on a three stage process: a preliminary assessment, simple contaminant measurements and, where warranted, complex measurements. The preliminary assessment consistes primarily of site inspections and occupant surveys. The second stage involves simple, usually inexpensive, contaminant measurements which, in most cases, identify the majority of problems. The final stage of the investigative process is requred only when careful evaluation during the first two stages has not identified both the causes and probable solutions to any detected problems.

Section 2.0 of the manual describes the preliminary assessment and specific contaminants of concern to air quality in highrise residential buildings. Section 3.0 provides a number of checklists to assist in the preliminary assessment process. Section 4.0 describes measurement techniques that a technologist could undertake to help identify a problem.

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1.0 INTRODUCTION

The investigation of indoor air quality in highrise residential buildings can be broken down into three basic stages:

- a preliminary assessment,
- simple measurements, and
- complex measurements.

The preliminary assessment consists primarily of site inspections and the investigation of potential problems or complaints. Essentially, it involves the application of common sense and observation in an attempt to identify the likely causes of problems.

Simple measurement techniques are those techniques which a reasonably knowledgeable, but not specially trained, technologist could undertake with the appropriate instruments and samplers. The results, in conjunction with information from the preliminary investigation, should identify the vast majority of problems.

The more complex measurement techniques may require the services of an expert in the field and are usually more costly. In most cases, they are necessary only if careful evaluation during the first two stages has not identified both the causes and likely solutions to the detected problems.

In general, achieving acceptable indoor air quality in a building requires:

- reducing, to as low as is practically possible, all contaminant sources;
- collecting and eliminating (exhausting) airborne contaminants as close as possible to their source;
- providing an adequate level of fresh air ventilation;
- using the space in a manner for which it was designed; and
- eliminating other environmental "stressors", physical or otherwise, to avoid confusing their effects with the effects of indoor air pollution.

In other words, it is not sufficient to ventilate a building according to recognized standards if there are particularly strong sources of contamination in the space; nor will ventilation be effective in removing odour if the flow path of ventilation air tends to spread odors rather than remove them at the source. No remedial action is likely to provide a cost-effective remedy if the right problem is not addressed. For example, there is no benefit at all to increasing ventilation rates if the root of an indoor air quality complaint lies with mould growth in a humidification system.

This manual provides a protocol for air quality assessments in highrise residential buildings based on a three stage process. Section 2.0 describes the preliminary assessment and specific contaminants of concern. Although this section contains little new information to people practicing in the field, it provides a good primer for those who are not familiar with Indoor Air Quality assessments.

Section 3.0 provides checklists to assist in the preliminary assessment process. This can be copied for use in individual buildings.

Section 4.0 describes measurement techniques that a technologist could undertake to help identify a problem. These have been categorized into simple and complex tests.

2.0 PRELIMINARY ASSESSMENT

2.1 General Procedure

The preliminary assessment consists of collecting information which could be helpful in identifying possible pollutants, locating their sources, assessing the effectiveness of ventilation systems, and defining the nature and severity of the problems experienced. Information can be obtained from building plans, complaint records, inspecting different areas of the building, and interviews with occupants, managers and others. No measurements involving instruments are made at this stage. The information collected will, however, enable the person conducting the investigation to choose appropriate locations for later testing.

The preliminary assessment provides the greatest single opportunity to find the true cause of an indoor air quality problem. Information gathering techniques normally employed at this stage include three steps: occupant response sampling, pollutant source identification, and general mechanical systems observation.

Useful tools include: a flashlight, a screwdriver, an adjustable wrench, a two metre step ladder, smoke pencils (to check air flow directions), and the checklists from Section 3.0.

Step 1: Occupant Response Sampling

This is often the first and most important source of information. Sources include: interviews, questionnaires, and records of complaints.

It is not possible to measure and observe everything at all times. Occupant feedback can greatly reduce the investigative effort required. Although the subjective judgement of the occupants may be in error concerning the true cause of an indoor air quality problem, their observations can be an important source of information concerning if, where, and when an indoor air quality problem exists. Determining whether there is a spatial, seasonal, or daily pattern to problems can assist greatly in pinpointing the cause of a pollution problem. As well, it should be determined whether the noted problems are individual to specific apartments or general to the building's common systems.

Step 2: Pollutant Source Identification

The second most important way to gather information is by observing possible air pollution sources during a building walk through. Visual observation, smell, breathing or eye discomfort, and common sense should provide the greatest clues to the type and size of pollutant sources which could be present.

Common sources that may be visually identified and associated with air pollutants include:

- garages (combustion byproducts),
- open sumps (radon and moulds),
- laundries (humidity, chemicals from cleaning products),
- garbage handling facilities (moulds, odors),

- condensate draining from air conditioners (moulds, fungi, bacteria),
- wet building materials (moulds, fungi, formaldehyde),
- humidifiers (moulds, fungi, treatment chemicals),
- new furnishings (formaldehyde and volatile organic compounds),
- occupant activities such as hobbies which use solvents, glues, or other strong sources,
- new paint, carpet glue, etc. (volatile organic compounds),
- outdoor air (a variety of pollutants),
- smokers (a great number of irritating and carcinogenic substances),
- fuel burning appliances (combustion products),
- swimming pools (chemicals, chlorine, humidity and associated biological growth),
- pets,
- cleaning agents, and
- cooking odors

In an apartment building, it is necessary to recognize that problems could be associated with sources in a specific unit or from common elements. It is necessary to access all units where problems have been noted.

Step 3: General Mechanical Systems Observation

If the previous two steps have not indicated a good reason for an air quality problem to exist, then the general condition and operation of the mechanical systems should be examined. This should include the determination of:

General Type

Constant Flow, Variable Air Volume, etc.

Air Flow Pattern

Most apartment buildings have simple ventilation systems where one or more fans pressurize the corridors and exhaust provisions are made in the individual units. The latter can be either individual fans or central exhaust fan(s) which service a number of units. This approach is supposed to establish a flow pattern which restricts pollutants and odors generated in a unit from spreading through the corridors. This "corridor-to-unit" flow pattern can be reversed by improper balancing of the corridor pressurization system or by environmental effects such as wind and stack forces and other mechanical systems. An example of this would be apartment buildings with central air conditioning systems in which the cool air supply to the unit is less than the removal rate through return grilles and exhaust systems.

Wherever strong sources exist, ventilation systems should be checked in order to ensure that they are performing in a reasonably satisfactory manner. In general, the ventilation system should exhaust strong sources directly outside.

Fresh air rates

- constant and economizer cycle;

Location of fresh air inlets

- and possible sources of exterior contaminants;

Local Exhausts

- where are they?
- what rules do they operate from?
- are they adjustable?

Controls

- type, mode of operation, general strengths and weaknesses, general condition and state of upkeep;

Details of operation

- hours of operation, strategy for operation of separate ventilation systems;

General condition and cleanliness

- of filters, humidifiers, cooling towers, air handling components;

Garage ventilation

- method, hours of operation, control, condition, operation against stack forces; and

Pool ventilation

- type.

Section 2.2 of this document describes some of the specific indoor air quality concerns potentially encountered in an apartment building. Section 3.0 provides checklists that can be used to organize the investigation process.

2.2 Specific Concerns

2.2.1 Carbon Dioxide

Carbon dioxide is produced both by the occupants of the building and by inadequately vented combustion devices. In office buildings, CO_2 is considered one of the prime indicators of a lack of adequate ventilation. In apartment buildings, population density is much less significant except perhaps in assembly areas which may have high "people loads" for relatively short periods of time. The CO_2 levels in most areas would not be expected to build up to the 800 - 1,000 ppm range common in offices. If it did, very restricted ventilation or another source of CO_2 would be expected.

Exhaust products from fuel-fired equipment could be a source of CO_2 if they are inadequately vented. If this is suspected refer to Subsection 2.2.2.

2.2.2 Carbon Monoxide/Combustion Products

CO, which is toxic, is primarily a product of incomplete combustion such as that which occurs in internal combustion engines. With clean burning flames, CO levels can be quite low and the primary product is CO_2. Nitrogen oxide is also formed in fuel burning operations. It has been noted as a problem with unvented appliances such as gas stoves.

The plans or discussions with the building operator and occupants will reveal the presence of possible problems in the building such as:

- internal parking garages,
- free standing fuel-fired heaters,
- kitchens with gas-fired stoves,
- furnace rooms for fuel-fired central heating systems and DHW systems,
- occupied areas close to any of the above, and
- air intakes close to other exhausts or to a street carrying heavy traffic.

2.2.3 Humidity

Health and Welfare Canada suggests that humidity levels be maintained between 30 and 80% RH in the summer and 30 and 55% RH in the winter.

Humidity levels below these ranges can result in symptoms of irritation, particularly in people who have respiratory problems. The primary concern with high humidity levels is that water can condense on cold surfaces, such as water pipes or poorly insulated walls and windows. This condensation can occur in concealed areas if air leakage leads to the cooling of exfiltration air in the building envelope. Water can damage the building in its own right, but it also provides one of the necessities for fungal growth. Constant wetting due to condensation can lead to mildew and other fungal growth. Some species of fungi are toxic, and a great variety of others cause allergic reactions in particular individuals.

The issue of biological contamination is dealt with in Subsection 2.2.8.

The level of humidity in individual apartments can be expected to vary a great deal depending on individual water generation rates and the level of ventilation. It is quite possible to have a localized problem affecting residents of individual units.

2.2.4 Formaldehyde

Plans or records of construction or renovation should indicate whether urea formaldehyde foam insulation (UFFI) may have been installed in the building envelope. If it was, the amount used should be determined and information obtained on efforts made to seal it from the indoor air. UFFI is potentially a strong source of formaldehyde.

Records should also indicate which parts of the building have been renovated (structural alterations, painting, replacement of ceiling tiles or carpets) in the past month. Formaldehyde is a component of many synthetic materials and adhesives. These areas should be inspected and the nearby residents should be interviewed.

Another potential source of formaldehyde is construction materials such as particleboard, particularly if it is wet. Sealing these materials can reduce emissions.

Normally, two coats of polyurethane varnish or vapour barrier paint are necessary for adequate protection.

Cleaning and maintenance procedures (such as washing walls and carpets or applying furniture polish) can also lead to the release of formaldehyde into the air. The timing of complaints should be checked to see if it coincides with activities of this type.

Symptoms of formaldehyde exposure include: difficulty breathing, eye, nose and throat irritation, headaches, coughing, fatigue, nausea and skin rashes. As these symptoms also occur with exposure to other organic compounds, they are not in themselves diagnostic of pollution due to formaldehyde.

Because many of the sources are building and furnishing materials, the emission rate should be fairly constant. Thus, if ventilation rates vary, symptoms will be worse in periods of low ventilation. If the timing of symptoms correlates with cleaning activities, this is reasonable evidence that the cleaning materials are responsible. However, chemicals other than formaldehyde in the cleaning materials could also be responsible.

In all likelihood, the only formaldehyde sources which are likely to be identified during the preliminary assessment are poorly sealed UFFI and large amounts of unsealed particleboard or plywood. It is much more probable that an apartment building will contain a myriad of weak sources. These can be difficult to identify. It is possible that the preliminary assessment will not provide evidence for a formaldehyde problem and the simple measurement techniques of Section 4.0 will be required.

2.2.5 Particulates

While particulates (dust and fibres) are not usually a problem in apartment buildings, an inspection (walk through) of recently renovated areas, the mechanical rooms, and any areas from which complaints have been received should be carried out.

The most likely sources of particulates inside a building are:

- renovations,
- outdoor air,
- ventilation ducts,
- humidifier deposits in areas with hard water, and
- smoking.

The evidence pointing to each of these sources is indicated below. As in the case of some other air pollutants, symptoms arising from exposure to particulates are non-specific and should not be used to identify sources in the absence of physical evidence for their existence.

- Renovations involving structural changes will almost certainly cause a particulate problem. However, since the particles tend to be large, the problem should not extend far beyond the space being altered (unless particles are carried by the ventilation system); nor should it persist for long after the renovations are completed.

- Outdoor air is unlikely to be the cause of particulate problems if properly maintained filter systems are installed in the air intakes. However, if there is

no filter system and any type of loose material is observed around the intake, then outdoor air may be implicated. Allergies appearing during the pollen season are also probably caused by outside air (pollen could be removed by a filter unit).

- Dirt around the diffusers indicates particulates are being introduced into the area by the ventilation system. These particulates may originate in the ventilation ducts if the building is old, if the ducts have never been cleaned or if there is insulation on the inside surface of the ducts.

- Chalky deposits around diffusers may be hard water minerals coming from humidification equipment. Observation of hard water deposits on humidifier vanes, complaints of dust, cement, or plaster-like odors when the humidifiers are operating or after they have been cleaned would provide additional evidence. Obviously, problems from this source will be most severe in winter.

Symptoms of particulate exposure include: dry eyes, nose, and throat, and the effects of dust irritation such as coughing, sneezing, and respiratory allergies.

2.2.6 Radon

Radon is an odorless gas originating in the soil. It can be introduced through below-grade air leakage and, under certain circumstances, dissolved in water. The following areas should be inspected for below-grade entry paths:

- basement or sub-basement areas
- rooms containing sump pumps
- areas where large volumes of air from the basement could be entering the above-grade portion of the building (such as through the top of the stairwell or through the elevator shafts).

During or after the inspection, the following questions need to be answered:

- Is there ventilation in these areas?
- Do people spend a significant part of the day in any of these areas?

There is a real possibility of problems with radon at a location if the following three conditions are met:

- The location has a potential strong source of radon, such as contact with the soil;

- Ventilation in that part of the highrise is minimal or absent, or there are odors (which are a useful indication of whether existing ventilation is operating properly); and

- People spend time in these areas, or nearby.

2.2.7 Volatile Organic Compounds

Many different chemicals can originate from building materials, furnishings, fixtures and the materials kept by occupants of a building. The concentrations of volatile organic compounds (VOCs) are likely to be low, however, unless there are major sources and/or very poor ventilation. Potential sources include:

- storage areas for chemicals such as pesticides, painting and solvents;

- cleaning and maintenance activities (including painting, recarpeting, structural changes and sealing); and
- occupant activities, such as hobbies, that use solvents.

Building records, maintenance schedules, and interviews of occupants should be used to obtain basic information about the building and the location of potential sources. These areas should then be inspected.

The symptoms experienced by people exposed to VOCs include: coughing, sore throat, faintness, nausea, fatigue, headaches, watery eyes, blurred vision, nervous stomach, skin irritation and allergies. These are non-specific and are not usually sufficient to identify individual chemicals. For this reason, the nature of the symptoms is less useful than information about when and where it was noticed.

2.2.8 Biological Contamination

Moulds and their spores are the most common type of biological contamination found in residential buildings. Some species of mould induce allergic reactions in a very broad spectrum of people, while other species are toxic to a select number of people only. Biological contamination is primarily found when suitable wet or damp breeding grounds exist. Therefore, one of the most important things to look for is signs of periodic wetting or an indication of a "water crisis" occurrence such as flooding or an overflow.

Fungal growth on surfaces like walls and ceiling tiles is usually dark brown or black. Green, white, blue-green and yellow colors can also occur with some species. Fungal colonies can be dense dark piles of spores that are slightly raised above the surface of their substrate. The spore of well developed colonies can be removed by rubbing. Examine the top side of removable ceiling tile. Things which could be mistaken for fungal growth include rust staining and burn marks (plumbing torches).

On carpets that remain damp and undisturbed (no traffic), fungus may develop as visible black, grey, or green patches on the surface. These patches can be circular in shape if they start at a point where they can radiate in all directions without being disturbed or interrupted. More likely, fungal colonies will form on the jute backing or underpad of the carpet. One should look for carpet stains that indicate water activity, such as evidence of stretching and rusty nails in the tack strip. If these are noticed, try to peel back the carpet at a convenient point and examine the jute backing and underpad for staining. Most species of fungus usually show as brown or black areas, but they can also appear as olive green, green, blue-green or yellow-green. Not all stains on the underside of a carpet will be fungal. Coffee and coke spills and other water stains are virtually indistinguishable from fungal colonies when viewed by the unaided eye. If the carpet was wet for more than a week, repeatedly soaked, or in a traffic area that brings in moisture on shoes and boots, fungal development is inevitable on carpets containing biodegradable fibres (i.e., jute) or on top of foam underpads.

A large number of fungi will rapidly colonize materials like cardboard boxes, clothes, and paper. First check for dampness on the surfaces in contact with the floor. Look for mould colonies as described above. Colonies growing across clothing may give it a peppered appearance. The "pepper" can be large spores of some fungus species.

In standing water, bacteria or algae (when visible) will add cloudiness to the water, form slime or accumulate in a bottom sludge. Only a few groups of fungi will develop

in water, but colonies are likely to occur just above the waterline as a black "tub" ring. Mineral precipitates could also form in water as a sludge and confuse the issue.

Some general guidelines for assessing the likelihood of microbial contamination in a building are indicated below:

- The presence of slime or mould in a humidifier or air-conditioning system or of mould in any of the ducts leading into or out of these units indicates a problem.
- Similarly, mould in ducts or on the surface of diffusers or exhaust louvres in an occupied area is a bad sign.
- The degree of contamination will increase if the ventilation is turned off for an extended period of time. The symptoms are likely to be more severe because of the lack of ventilation.
- Where there is a mouldy odour, there is probably also mould--although its location may not be immediately obvious.
- Damp spots on walls may be accompanied by fungal growth in the wall cavity.
- The temperature in the hot water tank should be maintained at a minimum of 75° C to eliminate legionnella bacteria.
- The spatial distribution of illness or complaints can be useful. If problems are widespread in the highrise, the contamination is probably in some part of the mechanical system.
- Problems are likely to be seasonal, involving humidifiers or condensation in winter and central air-conditioning systems in summer.

2.2.9 Ozone

Ozone can have significant, irritating effects on people. The primary source of ozone is arcing from high-voltage electrical systems; most notably from poorly operating electrostatic precipitators. These are not common in apartment buildings. If irritating symptoms are encountered where such units are operating, however, those units should be checked for cleanliness and a high level of arcing (snap and crackle on discharge). A second, relatively unlikely source of ozone is the high-voltage electric circuits in electrical vaults. Again, the problem is related to a dysfunction, and normally operating systems should not be producing ozone at significant levels.

2.2.10 Asbestos

Airborne asbestos fibres are a major air quality concern since asbestos is a known carcinogen. Asbestos was used as a high temperature pipe insulation and for fire protection of the structure. If it is fully contained so that fibres cannot escape into the air, it is of little concern unless renovations are planned. However, where coverings have degraded or were non existent, there certainly is potential for air contamination. Plans and inspections should determine if asbestos was used in construction and the potential for fibre release.

3.0 ASSESSMENT CHECKLISTS

This section contains two checklists. One for the building assessment and one for occupants to fill out.

The building assessment checklist has three sections:

I Building Common Areas
II Mechanical Systems and HVAC Operation
III Individual Apartment/Complaint Areas

Obviously, a number of the Section III checklists could be used in one building; and in some buildings, there may be enough of a separation of HVAC equipment to warrant use of separate Section II sheets.

The questions on the sheet are numbered 1 to 40. In many, there are supplementary questions noted as (a), (b), (c), etc. which are to be filled in if the answer to the main question is "YES".

In general, the "YES" answer implies there may be a source of air quality problems in this area.

Section 3.1 provides some advice on how to assess the response to individual questions.

I BUILDING COMMON AREAS

1. What year was the building constructed? _____
   a) Are the as-built design diagrams for this building missing? yes / no
   b) Are the current design diagrams for this building missing? yes / no
   c) Are the operating and maintenance manuals for the building's HVAC system missing? yes / no
   d) Is there no routine maintenance program for the HVAC system? yes / no

2. Have any areas been recarpeted recently? yes / no
   a) If YES, did odors persist for more than a week after carpet was laid? yes / no
   b) If YES, describe locations:

      _____

      _____

3. Have any areas been repainted recently? yes / no
   a) If YES, did odors persist for more than a week after the paint was applied? yes / no
   b) If YES, describe locations:

      _____

      _____

4. Has there been a recent or is there a regular cleaning process which uses large amounts of chemicals or solvents? yes / no
   a) If YES, what were the chemicals?

      _____

5. Is there a fuel-fired central heating unit or DHW system? yes / no
   a) Is there any physical evidence of leakage of combustion gasses from the furnace into the furnace or flue room or nearby areas? yes / no
   b) Is there the odour of combustion fumes in the room? yes / no

6. Is there an enclosed parking garage? yes / no
   a) Was the ventilation system found in an inoperative state? yes / no
   b) Is the ventilation system turned off for periods? yes / no
   c) Is the ventilation system controlled? yes / no
   d) Are there carbon monoxide sensors in the garage which control ventilation? yes / no
   e) If so, have they been recently calibrated? yes / no
   f) Are there obstructions in the exhaust or air inlets? yes / no
   g) Are stack forces sucking air from the garage into the building? (check at access doors) yes / no

7. Is there a garbage handling facility? yes / no
   a) Is the vent system off or ineffective? yes / no

b) Is there an air flow pattern from garbage rooms or chutes into the rest of the building? yes / no

c) Is there an unusually bad odour or mouldy smell associated with system? yes / no

8. Is there a pool, hot tub, sauna, or workout room? yes / no

a) Does maintenance and cleaning appear to be irregular or inadequate? yes / no

b) Are there any "mildew" stains on walls, ceilings, floors, fixtures or items such as like shower curtains yes / no

c) Is there any condensation on walls, floors, windows or ceiling? yes / no

d) Does humidity appear very high? yes / no

e) Do any biodegradable products (wood, etc.) get wet regularly? yes / no

9. Are there any basement or sub-basement areas or crawl spaces with dirt floors? yes / no

a) Are there occupied areas nearby? yes / no

If YES, describe locations:

_____

_____

b) Do these spaces lack ventilation? yes / no

Are there musty odors in these areas or nearby? yes / no

10. Are there rooms with sizeable holes in the walls or floor, such as sump pits, gas and water entrances, cracks, etc.? yes / no

a) If YES, describe location(s):

_____

_____

b) Do these spaces lack ventilation? yes / no

c) Are there musty odors in these areas or nearby? yes / no

11. Is there foam insulation in the walls of the building? yes / no

a) The type of insulation is polyurethane / polystyrene / urea formaldehyde / unknown.

12. Do drawings show asbestos insulation for pipes, fire protection of structure, etc.? yes / no

a) If YES, does inspection reveal loose fibre especially near air handling equipment and ducts? yes / no

13. Has there ever been a "water crisis" such as a flood or overflow? yes / no

14. Are there any signs of moisture problems such as:

a) stains or dampness on walls, floors or ceilings? yes / no

b) stained, streaked, or damp carpets? yes / no

c) mouldy odors, or musty smells? yes / no

II MECHANICAL SYSTEMS AND HVAC OPERATION

If the building contains two or more towers or wings, each controlled by a different HVAC system, a copy of this sheet should be filled out for each.

15. Describe ventilation system:

_____

_____

_____

_____

16. Is the amount of fresh air used by the ventilation system the same all year round? yes / no

17. Is the ventilation system of the recirculating type? yes / no
    a) Does the HVAC system use an economizer cycle? yes / no
    b) What is the maximum percentage of fresh air used? ____%
    c) What is the minimum percentage of fresh air used? ____%
    d) What is the fresh air percentage just now? ____%

18. Air supplied to the floors by:
    constant volume systems / variable air volume (VAV) system / heat pumps / other / unknown?

19. Is there a corridor pressurization system? yes / no
    a) Is the "corridor-to-apartment" flow reversed? yes / no

20. At what temperature is the tank supplying hot water to the building maintained? ____°C

21. Are there distinct fresh-air intakes for the building HVAC system? yes / no
    a) Are there intakes below third floor level and above a busy street? yes / no
    b) Are there intakes within 10 metres (30 feet) of the entrance or exit to a parking garage? yes / no
    c) Are there intakes within 10 metres (30 feet) of the exhausts of this or an adjacent building? yes / no
    d) Are intakes near standing water or a cooling tower? yes / no
    e) Is there a build up of organic debris near the intakes? yes / no
    f) Are there any other sources of pollution near any of the intakes? yes / no

22. Does this building have a particulate (dust) filter system installed in the fresh air intake? yes / no
    a) Are the filters missing? yes / no
    b) Are the filters changed less frequently than recommended by the manufacturer? yes / no
    c) Do the filters fit so poorly that air bypasses them at the edges? yes / no
    d) Are the filters matted or dirty? yes / no
    e) Are the filters wet? yes / no

23. Are spray humidifiers used in this building? yes / no
    a) Are the spray humidifiers supposed to operate at this time of year? yes / no
    b) Are the spray humidifiers operating now? yes / no
    If YES, answer the questions below:
    c) Are the spray humidifier pans plugged so that they are not draining properly? yes / no
    d) Is there slime in the humidifier pans? yes / no
    e) Are there mouldy odors? yes / no
    f) Is there mould in the ducts near the humidifiers? yes / no
    g) Is there evidence of foaming in the humidifiers? yes / no
    h) Is the water hard in this region? yes / no
    i) If so, are there hard water deposits on the vanes? yes / no
    j) Are the hard water deposits removed by scraping the vanes and blowing the dust into the ducts? yes / no

24. Are steam humidifiers used in this building? yes / no
    a) Are the steam humidifiers supposed to operate at this time of year? yes / no
    b) Are the steam humidifiers operating now? yes / no
    If YES, answer the questions below:
    c) Are chemicals used in the boiler or the pipes to protect against corrosion? yes / no
    If YES, state names of chemicals:

    _____

    _____

    _____

25. Does this building have an air-chilling system? yes / no
    a) Is the chilling system supposed to operate at this time of year? yes / no
    b) Is the chilling system operating now? yes / no
    If YES, answer the questions below:
    c) Are the condensate trays cleaned less often than once a week? yes / no
    d) Is there slime or growth in the condensate trays? yes / no
    e) Is there dirt on the cooling coils? yes / no
    f) Are there mouldy odors in the system? yes / no

26. Are the ventilation ducts or plenums insulated? yes / no
    a) Is the insulation on the inside and directly exposed to the moving air? yes / no
    b) Is it more than five years since the ducts or plenums were last cleaned? yes / no

27. Are there any signs of condensation in ducts? (Check cold spots such as near inlets and after cooling coils first.) yes / no

III INDIVIDUAL APARTMENT/COMPLAINT AREA OBSERVATION SHEET

No:_____

Where in the building do these observations apply? Please give the floor, room or apartment number or briefly describe (e.g. main lobby, everywhere):

_____

_____

Please answer all questions by circling or filling in the answers as required.

28. General Observations
    a) Are there damp spots or mould on the walls or ceiling? yes / no
    b) Are any of the carpets, curtains, etc. damp? yes / no
    c) Are there many potted plants in this area? yes / no
    d) Is there mould on the plants or their pots or soil? yes / no
    e) Do mites appear to be on the plants? yes / no
    f) Are there pets in the unit? yes / no
    g) Are there odors here? yes / no
    h) Which of the following best describes the odour?
    auto exhaust / diesel fumes / furnace room / heating system / pet odors / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty / chalky
    i) Are people using fans to create more air movement? yes / no
    j) Is there much dust visible on flat surfaces? yes / no
    k) Is there evidence of condensation on windows or walls? yes / no

29. Are there **air supply diffusers**? yes / no
    a) Can you see any of the following around the diffusers?
    mould / chalky dust / dirt marks yes / no
    b) Are any of the air supply diffusers blocked by furniture, paper, or other obstructions? yes / no

30. Are there any **air exhaust fans** or **louvers** in unit or complaint area? yes / no
    a) Do they have a poor drain rate? yes / no
    b) Are there dirt marks around the air exhaust louvers? yes / no
    c) Are any of the air exhaust louvers blocked by furniture, papers or other obstructions? yes / no

31. Has carpeting or furniture been installed in the last three months? yes / no

32. Are there large areas of particleboard sheathing or furnishings? yes / no

33. Is there a gas stove? yes / no
    a) Are there exhausts to remove combustion gasses produced by the stoves? yes / no
    b) Are the stoves operated without exhaust fans on? yes / no

34. Is there a wood or gas fireplace in the area? yes / no
    a) Does it appear to be poorly vented? yes / no
    b) Does it appear to have inadequate supply air? yes / no

35. Is there a freestanding heater (gas or kerosene)? yes / no
    If YES,
    a) Are these heaters used in anything but well ventilated spaces? yes / no
    b) Is there an odour of combustion fumes in the room? yes / no
    c) Is the room exhaust recirculated rather than directly expelled outdoors? yes / no

36. Is there a refrigerator in the unit? yes / no
    a) Does anything in the fridge look mouldy? yes / no
    b) Is the refrigerator drain blocked? yes / no
    c) Is the drain pan wet and mouldy? yes / no
    d) Are the heat exchangers dusty? yes / no

37. Is there mould on bathroom tiles, walls or ceilings? yes / no

38. Are there humidifiers or dehumidifiers in the unit? yes / no
    a) Do the drip pans, coils, and water in these units have accumulation of dust, slime, sludge or mould? yes / no

39. Are there small but steady leaks in, around, under or behind sinks, toilets, tubs and/or sewers? yes / no

40. Are there poorly sealed mechanical/electrical chases or other entry paths for contaminants from outside the unit? yes / no

OCCUPANT COMPLAINT SHEET

Where in the building are your complaints worst? Please give the floor, room or apartment number or briefly describe (e.g., main lobby, everywhere):

_____

_____

Your answers to the questions below apply to this location. Where a choice is given, please circle the most appropriate answer. Enter your own answer where requested. Space for comment is provided.

1. Describe the usual temperature at this location:
   okay / too hot / too cold / sometimes too hot, sometimes too cold

2. How would you usually describe the air here?
   okay / drafty / stagnant / stuffy / stale / dry

3. Are you bothered by odour at this location? yes / no
   If YES, how often do you smell this odour?
   rarely / occasionally / frequently / all the time
   Which of the following best describes the odour?
   auto exhaust / diesel fumes / furnace smell / heating system / body odour / mouldy or musty / chemical / like solvent / (wet) cement or plaster / dusty or chalky smell
   What do you think causes the odour?
   _____

4. Can you "fix" any of the problems noted above? How? yes / no

5. Has there ever been a "water crisis", such as a flood or overflow, in this area or on the floor(s) above it? yes / no

6. Do you have a history of allergies? yes / no
   If YES, the type of allergy is:
   respiratory / skin / food / other
   Are your allergies worse while you are in this building? yes / no

7. From which of the following do you suffer that you think are due to the building?
   headache / tiredness / faintness / dizziness / nausea / stomach problems / skin irritation / dry eyes / itching eyes / watery eyes / blurred vision / stuffy nose / runny nose / sneezing / sore throat / dry throat / chest problems / coughing / asthma

8. What time of day are your complaints worst?
   morning / afternoon / evening / night / the same all the time
   What day of the week are your complaints worst?
   weekday / weekend / the same all week

9. Do the symptoms coincide with or occur soon after cleaning or maintenance activities in this area? yes / no

If YES, describe this activity:

_____

_____

_____

_____

Comments:

_____

_____

_____

_____

_____

_____

_____

_____

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_____

3.1 Assessment Summary

In general, three factors must be addressed before the decision is made whether an air quality problem warrants further investigation. They can be remembered as PIP--People, Inadequate Ventilation, and Pollutants. The presence of people is important; problems can sometimes be tolerated in unoccupied areas such as basement mechanical rooms. The level of ventilation provided to a space generally must balance the level of contaminants produced in that space; adequacy should be judged based on looking at both factors.

The assessment checklists are designed so that a 'YES' answer to a question implies that a problem is possible, not that there is one. With the subsidiary questions, the more yeses, the more likely a problem exists. The following notes refer to the question numbers of the assessment form and provide some guidance in this judgmental process:

Question No.

1	Clarifies the adequacy of the information on which the assessment is based
2 through 14	Assesses the pollution sources in the building. Specific possible concerns by question are as follows:
2 through 4	Volatile Organic Compounds
5	Combustion products related to heating systems
6	Carbon Monoxide from parking garages
7	Odors and biological contamination associated with garbage
8	Humidity and related fungal growth
9	Radon and humidity related fungal growth
10	Radon
11	UFFI
12	Asbestos
13 and 14	Fungal Growth

II Mechanical Systems and HVAC Operation

15 through 19	define what kind of controlled mechanical ventilation is provided in the building. Many highrise residential buildings do not have circulation systems, but are ventilated through natural driving forces through infiltration by a corridor pressurization system.
20	If the temperature is higher than 60°C, Legionnella bacteria are unlikely to survive and breed.

21	Carbon monoxide can be a problem if intakes are either just above a busy street or close to a loading dock or parking garage that has been identified as a potential problem source. Contaminated air from an exhaust can re-enter the building if intakes and exhausts are too close together. Organic debris or standing water can lead to biological contamination.
22	Particulates may be a problem if there are no filters or if they are poorly maintained. Constantly wet filters can be a breeding ground for fungi.
23	Biological contamination can be caused by spray humidifiers if the pans are not kept clean. If there is a high level of dissolved minerals in the water, particulate problems can also result.
24	Chemicals used to protect the boiler or steam pipes may enter the ventilation system and be distributed around the building.
25	Biological contamination can result if the air conditioning system is not cleaned regularly. This is related primarily to bacterial or biological growth in standing water from condensate.
26	Particulates or insulation fibres (especially dirt) originating in ducts can sometimes be accumulated if the ducts are insulated on the inside.
27	Biological growth can result from condensation. Odors are one external clue. Direct observation can be difficult.
28	General observations give clues that there may be a problem
29	Look for any indication of dirty duct work creating particulate problems of poor air distribution caused by blocked air inlets
30	Same as above only in the opposite direction
31 and 32	Primarily concerned with formaldehyde VOCs emitted from glues and solvents in the furniture
33 through 35	Combustion products
36 through 39	Common sources of fungal contamination
40	Looking for possible entry routes of contaminants produced outside of the unit.

4.0 MEASUREMENT METHODS

4.1 Suggested Measurement Capabilities

In most cases, the findings of the preliminary assessment would determine which contaminants to measure in a particular building. In situations where a test kit suitable for a broad range of buildings is desired, the following measurement capabilities are suggested. They have been selected for relevance, accuracy, level of simplicity and cost.

Temperature and **humidity** should be assessed in most cases. A variety of tools are available for sampling humidity. Buchan, Lawton, Parent Ltd. has had success with relatively simple aspirated psychrometers. As well, a number of electronic instruments, most notably the Vaisala HMI 31 series, are accurate and simple to use. We do not recommend the use of the manual, sling-type psychrometer because accuracy depends so much on the operator.

A GASTEC sampling pump and Colorimetric tubes for **carbon dioxide**, **carbon monoxide**, **ozone**, **formaldehyde** and **hydrocarbon solvents** can be good screening tools. The accuracy of these tubes is only ± 25% and the range of some tubes, particularly hydrocarbon solvents, does not detect down to the low levels of pollutants that may indicate concern about long-term exposure. They can, however, provide a simple to use, relatively inexpensive indicator of major problems.

An **Infrared Carbon Dioxide Analyser** (Buchan, Lawton, Parent Ltd uses the Nova 305 SBDL, but there are several others including the Fuji ZFP5, the Horiba APBA 210, and the GASTEC R1-411 which have been evaluated as satisfactory by Public Works Canada).

An electro-chemical **carbon monoxide detector**. (Buchan, Lawton, Parent Ltd. uses the dual purpose Nova 305 SBDL. Public Works Canada has judged the CO 260 monitor from Industrial Scientific Devices as satisfactory. This is available from at least one rental company).

A chemical sampler for **formaldehyde**. When limited time is available, Public Works Canada recommends the STC formaldehyde monitoring kit which uses a passive bubbling sampler and individual reagent tablets. This method is relatively simple and self-contained. For residential occupancies, longer term sampling is more appropriate. One suitable sampler is the Air Quality Research Incorporated PF 1 sampler which requires laboratory services and, therefore, can be relatively expensive to use in any quantity. It is well recognized, however, and very easily used.

A number of electronic measuring devices are available for measuring **respirable suspended particulates** which use either a light scattering or piezoelectric mass monitoring principle. These instruments are really not suited for the low level of particulates expected in an apartment. We would not, therefore, suggest measuring particulates as a normal activity unless a problem is suspected. If this is the case, it is usually simpler to use a gravimetric method involving the sampling of air through a filter. The filter is weighed before and after sampling to find the weight of the particulates collected. The sampling pumps are relatively expensive (about $1,500), but at least one rental company rents them individually or in groups of five for reasonable daily rates. The dust can be examined through a microscope to determine whether it contains asbestos or other specific materials.

Radon samplers come in a variety of forms. Charcoal canisters are most commonly used, but Buchan, Lawton, Parent Ltd. prefers the **R.A.D.** system involving an active sampling approach measuring radon daughters (output in working levels). The R.A.D. system is typically deployed for one week.

Measurement for airborne **biological contamination** cannot really be considered a simple measurement technique. A number of sampling methods (Anderson Sampler and Biotest RCS Unit) can provide an assessment of the level of airborne particles that can grow into fungal colonies on agar plates or strips. The results can be misleading and ultimately the species and source of innoculum should be determined. Samples of contaminated material should be sent to an expert for evaluation. (Buchan, Lawton, Parent Ltd. uses Residential and Industrial Fungal Detection Service, 4 Birkett Street, Nepean, Ontario K2J 2V8). If biological contamination is suspected, samples of the following sizes should be taken from the potential problem areas noted during the preliminary assessment.

Size and Type of Sample Required for a Biological Contamination Assessment

Standing water - a 30 ml sample collected in a sterile bottle.

Dust (from ducts etc.) - 2-5 ml samples collected in a sterile bottle.

Walls and Ceilings - the best sample is a 200 mm x 200 mm piece of the material itself. Where this is not possible, a number of 20 mm X 20 mm paint chips in a pill bottle or film cannister will do.

Carpet - If the carpet is to be discarded, several 200 mm X 200 mm pieces in separate envelopes is suggested. If this is not an alternative, use a sharp knife or scissors and tweezer to collect several stained fibers from the jute backing. Transport in a pill bottle or film canister.

The cost of sampling for **Volatile Organic Compounds** removes it from the "simple measurement" category. However, if arrangements are made with a laboratory which does airborne VOC analysis, collection of the samples can be done by "non-expert" personnel. If the laboratory is supplying sampling equipment, their instructions should be followed.

Another tool which can provide some information about the general "healthiness" of the indoor air, rather than measuring for specific contaminants, is a method called a **bioassay.** Bioquest International has developed one type of bioassay. Passive absorbent tubes are used to collect organic gases and particulates. The resulting mixture is introduced to colonies of nemotodes. Depending on how the colony grows in numbers compared to a control colony, a judgement can be made about the overall "healthiness" of the air.

More details on this equipment are provided later in this section, as well as information such as the target levels for gases measured, suppliers, range and accuracy.

4.2 Where and When to Measure

Assuming that potential air quality problems warranting investigation by measurement have been identified through the Building Checklists, the investigator would proceed to the second stage - measurement with simple instruments. When measuring pollutant concentrations, it is not enough to simply go to the areas indicated through the Checklist that may be the source of a problem and take measurements when it is convenient. Such data may be quite meaningless for a number of reasons:

- The severity of the problem may vary depending on the time of day and the day of the week.
- Outdoor air varies from place to place, and this is going to affect the air indoors.
- The equipment might not be working correctly.

For an effective assessment, it is important to choose the appropriate sampling time and to establish a baseline for the data by taking measurements at "control locations" for comparison to measurements made at the test locations. This approach allows adjustments for variations in outdoor air quality and compensates for some equipment malfunctions.

Suitable control locations are:

- the air intakes
- another outdoor location (if there is a chance that the intake air is being contaminated)
- places indoors assumed to be free of the pollutant being measured

Test locations should include:

- places the Checklist indicates may contain a source of the pollutant being measured
- complaint locations (pollutants can move around a building in surprising ways)
- the air exhausts

The monitoring of pollutants arising from the building structure, furnishings or ventilation (formaldehyde, some volatile chemicals, biological contamination, etc.) is not usually sensitive to time. However, pollutants generated by the occupants (such as carbon dioxide) or their activities (hobbies, cleaning, parking, etc.) are best checked when these activities have occurred.

The time of year also has to be taken into account. If the building has a variable air handling system, fresh air rates are likely to be less during very cold or very hot weather, the pollutant concentrations, therefore, will generally be higher in mid-winter and mid-summer. Some sources are also seasonal: humidifiers in winter, heating equipment in winter, air conditioning systems in summer, pollen in summer, etc.

The above discussion provides some general criteria to use when choosing where and when to make measurements. A more detailed examination of suitable locations for

taking control samples are listed in Table 4.1. Table 4.2 identifies suitable sampling locations and times for taking test samples. Table 4.2 refers to the pollutant sources and complaint locations identified in the Building Checklists.

Control locations are not used for temperature, relative humidity, and air movement measurements since these parameters are controlled by the mechanical systems of the building. Indoor values are expected to be different from outdoor values.

Usually, it is best to do the control and test measurements together, choosing a time appropriate for the test locations.

Table 4.1

SUITABLE CONTROL LOCATIONS FOR MEASURING POLLUTANTS

Pollutant	*Suitable Control Location*
Carbon Dioxide	- air intakes (if not contaminated) - outdoors - street level or roof - indoors - unoccupied area
Carbon Monoxide	- air intakes (if not contaminated) - outdoors - roof or upper floor - indoors - above second floor
Formaldehyde	- air intakes (if not contaminated) - outdoors - roof or upper floor on the building side of particulate filters - indoors - unoccupied area
Particulates	- air intakes (if not contaminated) - outdoors - roof or upper floor on the building side of particulate filters - indoors - unoccupied area
Radon	- outdoors - sheltered area (no wind or rain) - indoors - above second floor
VOC	- air intakes (if not contaminated) - outdoors - street level or roof - indoors - away from identified pollutant sources
Biological Contamination	- air intakes (if not contaminated) - outdoors - roof - indoors - area with no mould, water or plants

Table 4.2

TEST LOCATIONS AND IDEAL TIMES FOR MEASURING POLLUTANTS AND OTHER PARAMETERS

Pollutant or Parameter	*Test Locations*	*Time to measure*
Carbon Dioxide	- pollutant sources	- when heavily occupied - when fresh air rate low - when combustion products could be produced
Carbon Monoxide	- pollutant sources - complaint areas - stairwells linked to sources - elevators linked to sources - exhausts	- when fresh air rate low - when combustion products could be produced
Formaldehyde	- pollutant sources (building) - complaint areas	- when fresh air rate low
Particulates	- pollutant sources - complaint areas - exhausts	- when source is suspected
Radon	- pollutant sources	- when fresh air rate low
VOC	- pollutant sources (building) - complaint areas - exhausts	- when fresh air rate low
VOC	- pollutant sources (activity) - complaint areas - exhausts	- late morning - late afternoon - when fresh air rate low - after cleaning/ maintenance
Biological Contamination	- pollutant sources (building) - complaint areas	- when fresh air rate low - summer
Humidity	- supply air - complaint areas	- midwinter - midsummer
Air Movement	- near diffusers	- while the ventilation system is operating

4.3 Contaminants and Measurement Methods

The following pages provide information on the contaminants discussed in this report and the measurement methods suggestioned by the authors of this report and the Architectural and Building Services Division of Public Works Canada.

In general, a number of optional instruments or methods are provided. It is likely that the availability of a particular instrument or method will be a major factor in a user's final selection. With each contaminant, "user notes" provide some guidance on the use of the instrument or method for measuring indoor air contamination levels. In these instructions, it has been assumed that the user has obtained and read the operations manual of the instrument in question.

4.3.1 Simple Measurement Methods

Contaminant:	**TEMPERATURE and HUMIDITY**
Sources:	HVAC and enclosure problems
Permissible Exposure Limits: (Residential)	*Humidity:* Health and Welfare Canada 30 - 80% RH summer 30 - 95% RH winter ASHRAE RH 25 - 65% *Temperature:* Winter 20 - 24°C Summer 22 - 26°C
Instrumentation:	VAISALA HMI-31/HMP-31UT ($1,000)
Supplier:	Hoskins Scientific 1156 Speers Road Oakville, Ontario
Rental Suppliers:	
Principle of Operation:	Temperature: Platinum Thermistor RH: Thin film plymer capacitor
Range:	Temperature: -40°C to +80°C RH: 0-100% RH
Accuracy:	Temp: ± 0.3°C RH: ± 2% RH in 0 - 80% range, ± 3% in 80 - 100% range
Other Instruments/ Methods:	Solomat MPM Series Aspirated Psychrometers

Contaminant:	**CARBON DIOXIDE** (CO_2)
Sources:	Human metabolism, combustion
Permissible Exposure Limits:	Health and Welfare Canada - 3,500 ppm Suggested limit for offices - 1,000 ppm
Typical Residential Indoor Levels:	400 - 600 ppm
Health Effects:	Headache, dizziness, drowsiness
Instrumentation:	- NOVA 305 SBDL, 306, 390 (3,500) - Fuji ZFP5 ($3,300) - Horiba APBA 210 ($4,200) - GASTEC RI-411 ($3,400)
Suppliers:	NOVA, Analytical Systems Inc. 7 Lansdowne Avenue Hamilton, Ontario Safety Supply Canada Analygas System Ltd., Scarborough Levitt-Safety Ltd
Rental Suppliers:	
Principle of Operation:	Non Dispersive Infrared (NDIR) Air is sampled and passed through an infrared beam. The CO_2 concentration is measured by the detector and output to the meter in PPM
Range:	0 - 3000 PPM
Accuracy:	± 5% Full Scale
Time Until Results:	Immediate
Other Instruments/ Methods:	GASTEC or Drager Detector Tube/Hand Pump ($150) (tubes 10 for $25) accuracy approx. ±25%

User Notes:

Infrared carbon dioxide instruments have become the standard method of measuring ambient carbon dioxide levels. The user must be well aware of two cautions, however, when using the instruments. They require time to warm up, and they are subject to drift with time, temperature, and transportation. The instruments require careful calibration procedures.

For calibration, two "known" test points are required in order to set the "Zero" and the "Span." A "Zero" gas can be obtained in one of two ways: either by using dry nitrogen (which contains no $C0_2$) or by the using a "scrubber" which removes $C0_2$ from the air. The former is preferable for bench calibration, but the scrubber does have attractions for field use. The second test point requires a calibration gas with a known quantity of

carbon dioxide in dry nitrogen. The concentration of CO_2 in the calibration gas should be at the upper end of the expected measurement range--for indoor air quality studies, 1000 parts per million (ppm) is appropriate.

An instrument should be bench calibrated before and after each day of testing. Rechecking the "Zero" in the field is also necessary, and it is at that time that a scrubber is particularly useful.

While the specific calibration procedures may vary slightly with instruments, in general they consist of:

- Turn on the instrument and let it run for at least 15 minutes to warm up.
- Fill a plastic bag with 2 or 3 litres of "Zero" gas and attach this to the inlet line. Wait for instrument to stabilize. This will typically take 5 or 10 minutes.
- Use the "Zero" adjust knob on the instrument and adjust it so that it reads 0 ppm.
- Transfer 2 or 3 litres of the "calibration gas" to a plastic bag and attach this to an inlet line. Wait for the meter to stabilize and then use the "Span Adjust" knob or pot to adjust the reading to match the known quantity of CO_2 in the calibration gas.
- Run "Zero" gas through the meter again and readjust the "Zero" setting of the meter if necessary. If a fairly significant adjustment is required, it may be necessary to re-set the "Span" using the calibration gas and re-check the "Zero" again until the user is confident that the instrument is reading the 2 points with the desired accuracy.

In the field, it will be necessary to re-check the "Zero" using either a "Zero" gas or scrubber. It is desirable, but not absolutely necessary, to check the upper range using the calibration gas.

Remember that the instrument takes a long time to warm up even after a momentary shut-down. Most instruments come equipped with battery packs and a power cord. If a long day of testing is planned, it can be useful to do as many tests as possible using the power cord, but the instrument must be left on at all times under battery power to avoid the wait for the instrument to warm up again each time.

Contaminant:	**CARBON MONOXIDE** (CO)
Sources:	Car and truck exhaust, fuel-fired appliances, kerosene heaters
Permissible Exposure Limits:	Health and Welfare Canada 25 ppm - 1 hr, 11 ppm - 8 hrs
Typical Indoor Levels:	0.5 - 2 ppm
Health Effects:	Headache, impairment of visual acuity and brain functioning. Death at 1000 ppm.
Instrumentation:	- NOVA 305, 390 SBDL (3,500) - CO 260 Monitor ($1,125) - Industrial Scientific Devices
Suppliers:	NOVA, Analytical Systems Inc. 7 Lansdowne Avenue Hamilton, Ontario Safety Supply Canada
Rental Supplier:	C0260 Available from Hazco Canada Inc. 6567 Mississauga Road Mississauga, Ontario K5N 1A6
Principle of Operation:	CO passes through a diffusion medium and is absorbed on an electrocatalytic sensing electrode. This generates an electric current proportional to the gas concentration.
Range:	0 - 1000 ppm
Accuracy:	± 1 ppm
Other Instruments/ Methods:	GASTEC or Drager Colorimetric Tube/Hand Pump ($150) (tubes 10 for $25) accuracy approx. ± 25%

User Notes:

The electro-chemical carbon monoxide instruments suggested for use require calibration. They are less sensitive than the Infrared CO_2 sensors and normally are not adjusted for span, but should have their "Zero" checked periodically. A "Zero" gas (dry nitrogen) or a scrubber can be used. Many of these instruments also have a long warm-up time and should be left to warm up for 15 minutes to half an hour before taking readings. Since they draw very little electrical power, the instrument's internal battery can be left on all day with no problem.

Contaminant:	**FORMALDEHYDE (CH_20)**
Sources:	UFFI, off-gassing of building materials (carpets, particle board, fabrics) Cleaning fluids, adhesives
Permissible Exposure Limits:	Health and Welfare Canada Target level - .05 ppm Action level - .1 ppm ASHRAE - 0.1 ppm average over 8 hrs
Typical Indoor Levels:	0.02 - 0.1 ppm
Health Effects:	Irritation of eyes and upper respiratory passages
Instrumentation:	AQRI PF1 7 day samplers, $40 each
Suppliers:	ORTECH International Sheridan Park Research Community 2395 Speakman Drive Mississauga, Ontario L5K 1B3 Air Quality Research Inc. 901 Grayson Street Berkeley, CA 94710 Air Technology Labs Inc. 548 Mallard Circle Fresno, CA 93710
Rental Suppliers:	
Principle of Operation:	Formaldehyde vapours diffuse down the container to a paper medium impregnated with an absorbing chemical. This is extracted in a laboratory and the time-weighted average exposure is determined.
Range:	0.02 - 10.0 ppm
Accuracy:	± 25%
Other Instruments/ Methods:	STC Formaldehyde Monitoring Kit (100 samples - $750)

User Notes:

The suggested sampling method for most residential applications is the Air Quality Research Institute PF1 Passive Dosimeter. It looks like a pill bottle. The dosimeter is uncapped and left on-site for approximately one week, re-capped, and sent to an analysis lab. In Canada, the samplers are supplied and analyzed by a number of commercial labs including ORTECH International in Toronto.

The samplers come in kits of two. A label on each sampler provides space to mark the start and stop time, and the date, and a ribbon and pin permit the sampler to be hung from ceilings, fixtures, or furniture. Since the sampler works by an air diffusion

method, it should not be hung near heating or ventilation system outlets where there may be drafts and should not be placed within six inches of walls or near windows. Each kit comes supplied with instructions on deployment.

Contaminant:	**RADON**
Sources:	Decay product of uranium, rises from the soil and is often trapped in buildings. Building materials: bricks, stone.
Permissible Exposure Limits: (Residential)	Health and Welfare Canada 20 pCi/L or 0.1 WL ASHRAE (EPA) 4 pCi/L or 0.02 WL
Typical Indoor Levels:	N/A
Health Effects:	Increased risk of lung cancer (Mesothelioma)
Instrumentation:	M-1 R.A.D. pump - week-long sampling device
Supplier:	R.A.D. Service and Instruments Ltd. Unit 208, 40 Silver Star Blvd Scarborough, Ontario M1V 3L3
Rental Suppliers:	
Principle of Operation:	Air is drawn through a filter which traps particles to which radon daughters are attached. As the radon daughters decay, they leave tracks on an "alpha track" detector. These tracks are counted manually in a laboratory.
Range:	N/A
Accuracy:	± 20%
Other Instruments/ Methods:	Long term (6 months) Alpha Tech Detectors ($35-50) Barringer Laboratories 5735 McAdam Road Mississauga, Ontario L4Z 1N9 Bubble Technology Inc. Highway 17 Chalk River, Ontario K0J 1J0 R.A.D. Charcoal Canister ($20) - short term screening device. Alpha Nuclear Co. 1125 Derry Road, East Mississauga, Ontario L5T 1P3 Direct Reading ($3,000 - $5,000) Pylon Electronic 147 Colonnade Road Ottawa, Ontario K2E 7L9 Thomson & Nielsen Ltd. 4019 Carling Avenue Phase I, Suite 202 Kanata, Ontario K2K 2A3 EDA Instruments Inc. 4 Thorncliffe Park Drive Toronto, Ontario M4H 1H1

User Notes:

The R.A.D. measurement system for Radon daughters is preferred over charcoal cannisters because its active sampling method is less subject to very localized effects.

The R.A.D. system uses a small air pump similar to an aquarium air pump and is not, therefore, silent. The noise is relatively innocuous so there are few occasions where this creates a significant problem.

The R.A.D. system can be obtained directly from R.A.D. at the address shown on the previous page or through Buchan, Lawton, Parent Ltd. It is supplied complete with the pump and the measurement head. The pump is plugged into 110 volt outlet and the start date and time noted. Make sure it is not plugged into a switched outlet. At the completion of sampling--typically a week, but it can vary from three days to a month--the pump is unplugged, the stop date and time noted, and the entire unit sent to the supplier. Turnaround time for the results is usually two to three weeks.

4.3.2 Complex Measurement Techniques

The following notes concern measurements which normally require the services of an expert and would not be suggested for most applications. Because they do require these expert services, they are also relatively expensive to undertake on a building. They would normally only be used when a problem is suspected based on preliminary assessment.

Contaminant:	**RESPIRABLE SUSPENDED PARTICULATE** (RSP)
Sources:	Tobacco smoke, incomplete combustion, renovations
Permissible Exposure Limits:	Health and Welfare Canada 100 $\mu g/m^3$ - 1 hr 40 $\mu g/m^3$ - long term average
Typical Indoor Levels:	30 - 200 $\mu g/m^3$ non-smoking 20 - 30 $\mu g/m^3$
Health Effects:	Dependent on the chemical and physical nature of particulates Can increase risk of lung cancer
Instrumentation:	Gravimetrically with pump and filter ($1,800 for pump) filter 37 mm Cellulose Acetate
Suppliers:	Safety Supply Levitt Safety
Rental Supplier:	Hazco Canada Inc. 6547 Mississauga Road Mississauga, Ontario L5N 1A6
Principle of Operation:	Air is pumped through a filter at a known rate for 4 - 6 hours. The filter is weighed in a lab before and after sampling and then the mass of particulates is determined.
Range:	
Accuracy:	
Other Instruments/ Methods:	MDA-PDC-1 Digital Dust Counter ($8,700) Piezoelectric Mass Monitor (TSI model 3500; $7,000)

User Notes:

The gravimetric analysis of filter samples is easy to perform with the proper equipment. In principal, a known quantity of air is pumped through a pre-weighed filter. When the filter is re-weighed after sampling, the difference is the total mass of particulates filtered out of the air. The calibrated air pumps required are relatively sophisticated and expensive, but they are available for rent. The 37 mm cellulose acetate filters and cassette containers are available from most safety equipment suppliers. Air pumps need to be calibrated and set for an appropriate flow rate--typically, 2 litres per minute. Calibration equipment can be a simple bubble tube or special calibrators such as the "Mini-Buck" calibrator which speeds up the procedure because they eliminate the need for stop-watch timing and calculation of flow rates.

The appropriate sampling period depends on the particulate loading in the air. In most residential applications, sampling for less than four hours is not likely to yield a significant load of particulates.

The weighing of filters requires precision balances, but there are many laboratories that have the appropriate equipment. It is necessary to condition the filters before both weighings (before and after) by placing them in an environment of controlled humidity and temperature. This eliminates any variation in weight of the filter itself due to humidity related water gain.

The particulates collected by the filter can be examined through a microscope to determine whether they contain biological particles such as mould spores and pollen and if they contain asbestos fibres or crystals. This is not normally required for indoor air quality analysis in highrise buildings.

Contaminant:	**ASBESTOS**
Sources:	Building materials, ceiling tiles, insulation
Permissible Exposure Limits:	ACGIH 0.5 fibers per cc Amosite 2.0 fibres per cc Chrysotile
Typical Indoor Levels:	N/A
Health Effects:	Increased risk of lung cancer (Mesothelioma) Asbestosis
Instrumentation:	Air sampling pump with air filter 37mm cellulose acetate (0.8u pore size)
Suppliers:	Millipore (filters) Levitt-Safety or Safety Supply (pumps)
Rental Suppliers:	
Principle of Operation:	Air is pulled through the filter at a known rate for 4 - 6 hours, the sample is then sent to the laboratory for microscopic fibre counting.
Range:	0.1 - 60 fibres per cc
Accuracy:	± 20%
Other Instruments/ Methods:	Transmission Electron Microscopy

User Notes:

See User Notes under "Respirable Suspended Particulates."

Contaminant:	**AIRBORNE MICROBIALS: FUNGI**
Sources:	Outdoor air and soil Improperly drained or maintained humidifiers Wet surfaces of HVAC systems Furnishings and ceiling tiles damaged by flooding
Permissible Exposure Limits:	ACGIH 1,000 cfu (colony forming units) per cubic metre of air 1,000,000 fungi per gram of dust 100,000 fungi per ml of stagnant water or slime AGRICULTURE CANADA <50 cfu/m^3, 2 species, or <150 cfu/m^3, 3 species, or <500 cfu/m^3
Typical Indoor Levels:	under 200 cfu/m^3, summer under 50 cfu/m^3, winter
Health Effect:	Allergic reaction to fungi can cause shortness of breath, coughing, sneezing, itchy eyes, or runny nose.
Instrumentation:	Biotest RCS Centrifugal Air Sampler ($2,300) with Rose Bengal Agar Strips (box of 50, $150)
Supplier:	Gelman Sciences 2535 Deminiac Street Montreal, Quebec H4S 1E5
Rental Suppliers:	
Principle of Operation:	Fungal spores drawn into the sampler are impacted by centrifugal force onto a strip of nutrient media (agar). After incubation, the number of colonies grown are counted and identified.
Range:	
Accuracy:	Sampled air volume ± 2%
Other Instruments/ Methods:	Andersen sampler for viable particles with pump

User Notes:

The Biotest RCS sampler is easy to use, but the data is difficult to interpret. Public Works Canada has used it for a number of years as a standard testing tool for airborne fungi spores in office buildings. The procedure recommended by PWC is:

- Sterilize fan blades and wipe them with an ethynol swab. This procedure should be done at the beginning of sampling and in major divisions, such as each floor of a large building.

- Open the Agar strip by pulling back the bubble pack cover a few centimetres. Without touching the Agar strip with your fingers, remove it from its covering and slide it, agar side in, into the drum of the instrument.

- Set sampling time switch to 4 minutes.

- Place the instrument in the required location and turn it on. Do not move the instrument while the sample is being taken. It stops automatically after the set sampling period.

- After sampling, remove the strip from the instrument and place it back in the original wrapper with the Agar side facing the raised surface of the bubble pack.

- Seal the opening with adhesive tape and mark the sample using a china marker for identification. Strips can be kept in a cooler for transport to the laboratory for incubation and examination for colony forming units and species identification.

The difficulty with the system is the need for qualified personnel to identify the species. Buchan, Lawton, Parent Ltd. uses the services of Residential Industrial Fungal Detection Services, 4 Birkett Street, Nepean, ON. There are also a number of university researchers who could perform this function.

In reality, assessing the significance of the biological testing results with this instrument is a job for experts. It cannot be classified as a "simple test" procedure.

Contaminant:	**VOLATILE ORGANIC COMPOUNDS**
Sources:	Building products, paints, sealants, glues, etc. Many cleaning products
Permissible Exposure Limits:	Not defined in Canada
Typical Residential Indoor Levels:	Under 2 mg/m^3 Total VOCs
Health Effects:	
Instrumentation:	Sampled pump air activated charcoal tubes analysed by gas chromatography.
Supplier:	Levitt-Safety Safety Supply
Rental Suppliers:	Hazco Canada (pumps only) 5667 Mississauga Road Mississauga, Ontario K5N 1A6.
Principle of Operation:	Air sample is pumped through an activated charcoal absorbant tube which is sent to a laboratory for analysis. Concentrated contaminants can be desorbed and analysed using gas chromatography or gas chromatography/mass spectrometry.
Range:	
Accuracy:	
Other Instruments/ Methods:	There are some infrared analysers which can give on-site readings of many volatile organic compounds; notably, the Moran 1B. This $30,000 instrument requires an expert operator.

User Notes:

Sampling for volatile organic compounds is not particularly difficult. The real complexity is in the analysis of results. A known volume of air is pumped through charcoal absorbant tubes that can be readily obtained from safety equipment suppliers. The tubes, along with information on the volume of air pumped through them, must be supplied to a laboratory with the capability to desorb and analyse the contents using either gas chromatography or gas chromatography/mass spectrometry. ORTECH International in Toronto is one lab offering these services, but there are a number of others.

Sample rates would be approximately 0.5 litres per minute and the sample time can vary. The longer the time, the more concentrated the sample and the easier it is to measure. Sample periods of as long as 20 to 30 hours are recommended, particularly if analysis is limited to gas chromatography. ORTECH will analyse samples with as little as 10 litres (20 minutes) at 0.5 litres per minute using GC/MS.